Optimizing the control of foot-and-mouth disease in Denmark by simulation

Foot-and-mouth disease simulation modeling

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Publication date:
2012

Document Version
Publisher's PDF, also known as Version of record

Technical University of Denmark

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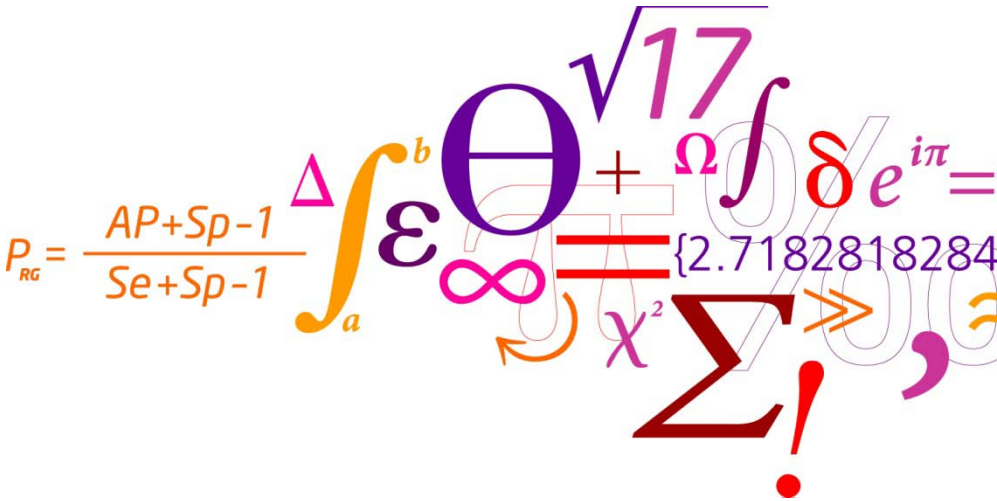


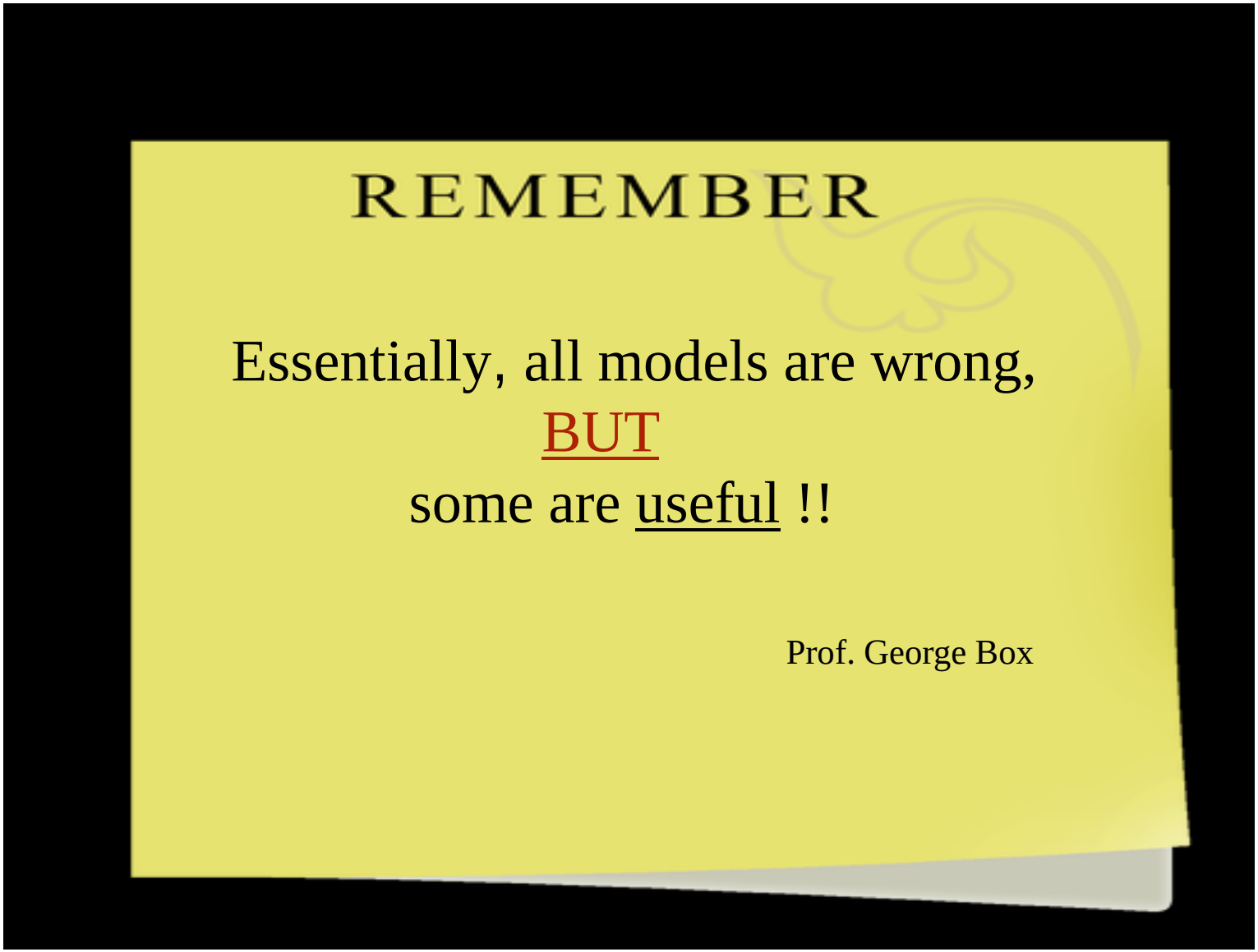
DTU Vet
National Veterinary Institute

Outlines I:

- Theoretical introduction to Monte Carlo simulation modeling:
  - What is Monte Carlo simulation modeling?
  - Why Monte Carlo simulation modeling is used?
  - When is it appropriate to build a simulation model of a system?
  - What do we need to build a model?

Outlines II:

- Foot and mouth disease (**FMD**) simulation modeling as illustration with emphasis on different ways of modeling:
  - Animal model.
  - Disease evolution within a herd.
  - Disease evolution within a country.
- Minimum required data to build a useful FMD model.

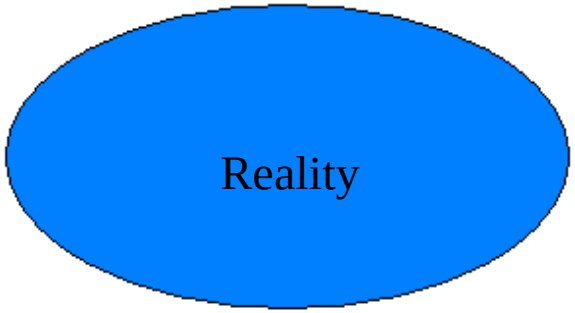

REMEMBER
Essentially, all models are wrong,
BUT
some are useful !!
Prof. George Box

Simulation modeling

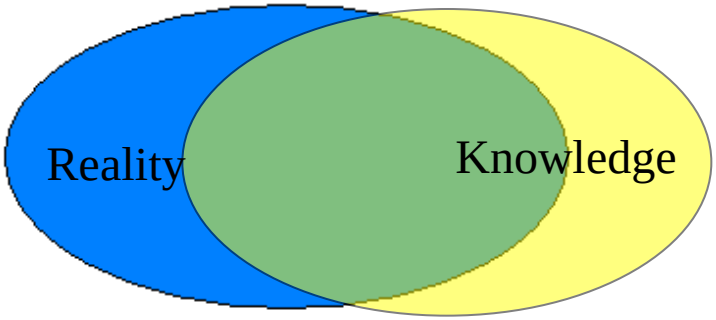
- A representation of real life systems to gain insight into their functions and to investigate the effects of alternative conditions or actions on the modeled system.

- It is frequently referred to as Monte Carlo simulation.

A simplification of a system (e.g. FMD)



A simplification of a system (e.g. FMD)



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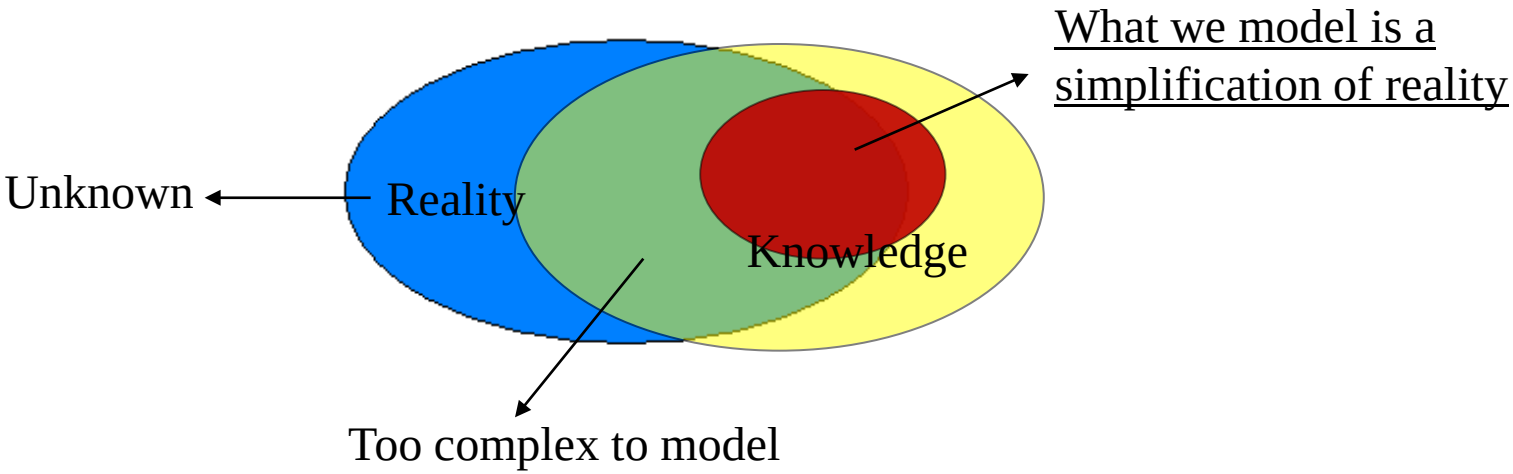


Why simulation modeling is used?

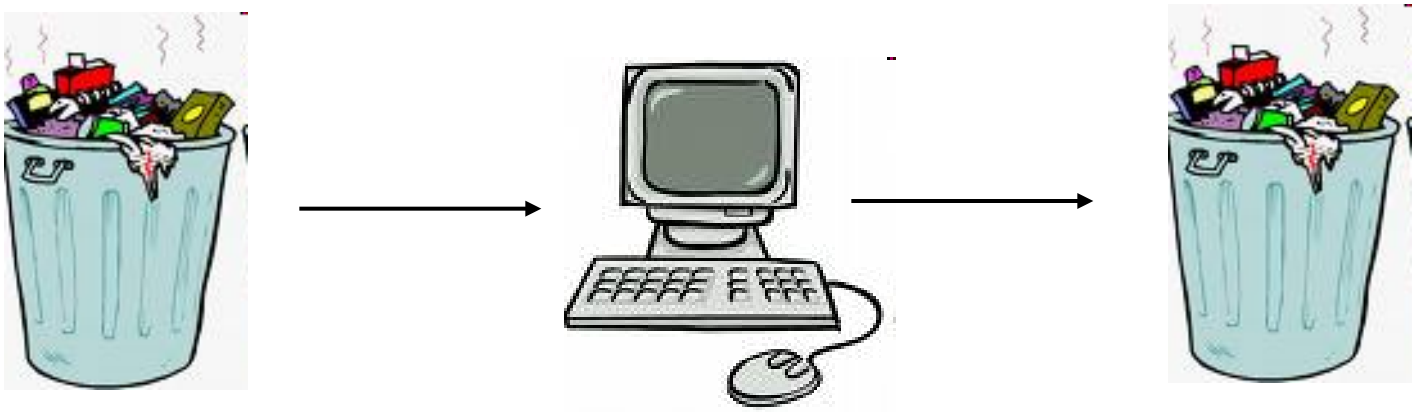
- It is best to use experiments and trials to investigate the effect of alternative conditions or actions on a specific system.
- Experiments and trials are very expensive.
- Not an option to conduct a field trial (FMD).

Simulation modeling?

- Cheaper choice.
- As soon as the model is validated, further changes to examine alternative choices and actions can be incorporated quite fast and easy.
- Therefore, models can be a good alternative to experiments, given the limitations.

When is it appropriate to make a model?

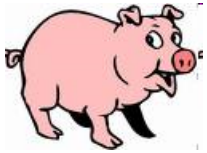
- Only when sufficient basic information regarding the modeled system is available.



The models

- DTU-DADS: updated model of the **D**avis **A**nimal **D**isease **S**pread (version 0.05).
- **I**nter**S**pread **P**lus (version 2.001.11).
- **N**orth **A**merican **A**nimal **D**isease **S**pread **M**odel (version 3.0.81).

Animal model of FMD

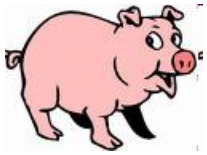


Healthy susceptible

FMD Infected

Removed

Animal model of FMD



Healthy susceptible

FMD Infected

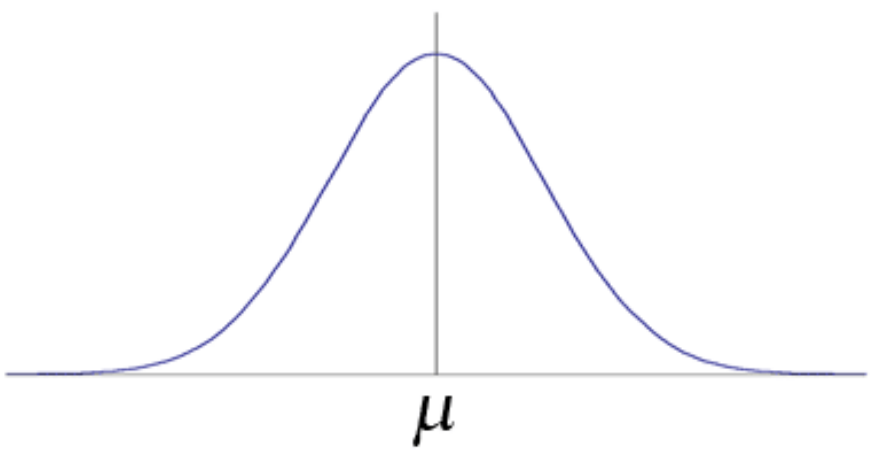
Removed

The progress of the animal in the different stages is controlled by **probabilities** of infection and detection.

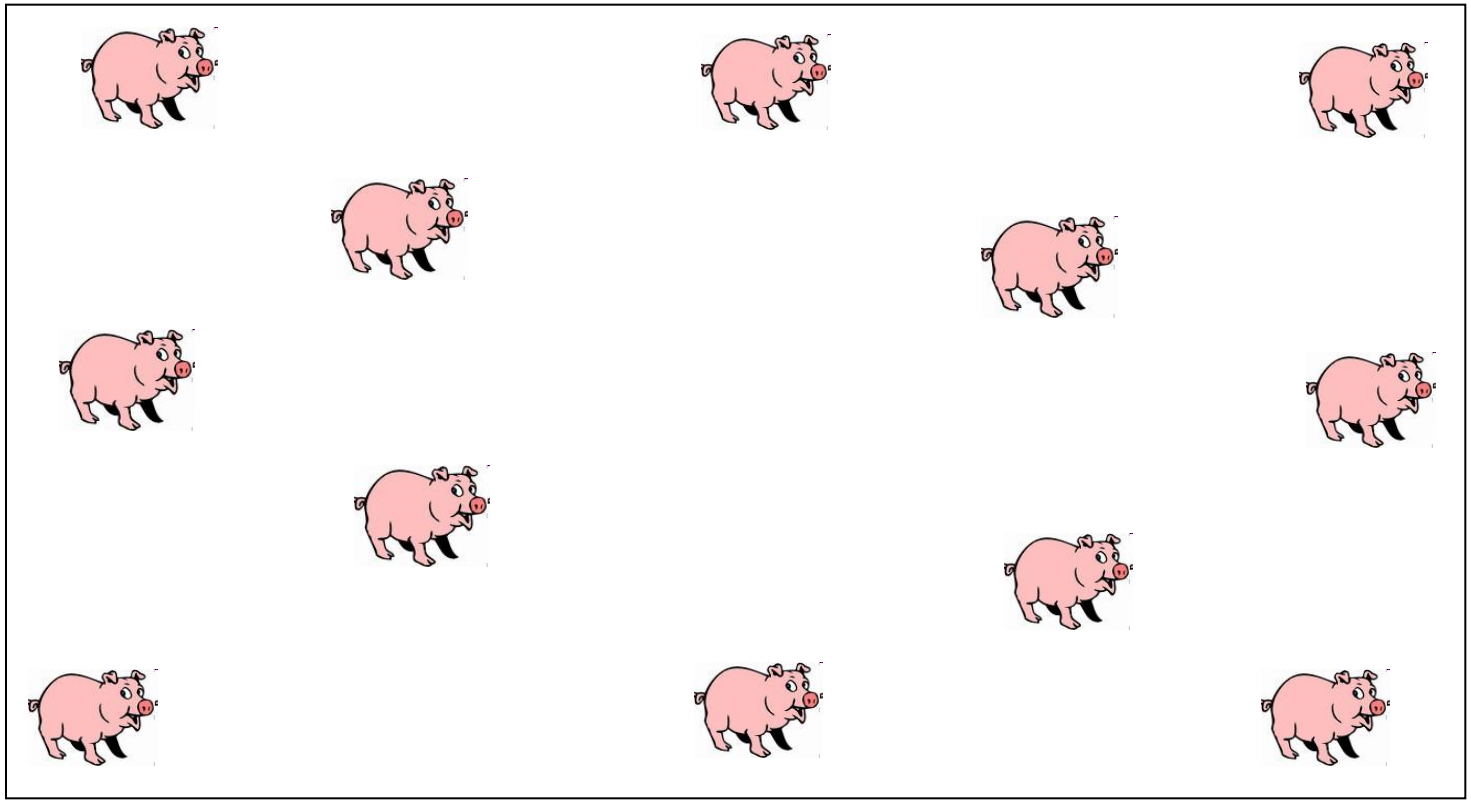
Deterministic vs. stochastic

- Deterministic: use one input value to represent the occurrence of an event; for instance the use of average value.

- Stochastic: use randomness to model chance or events; for instance the use of probability distribution.



A herd model



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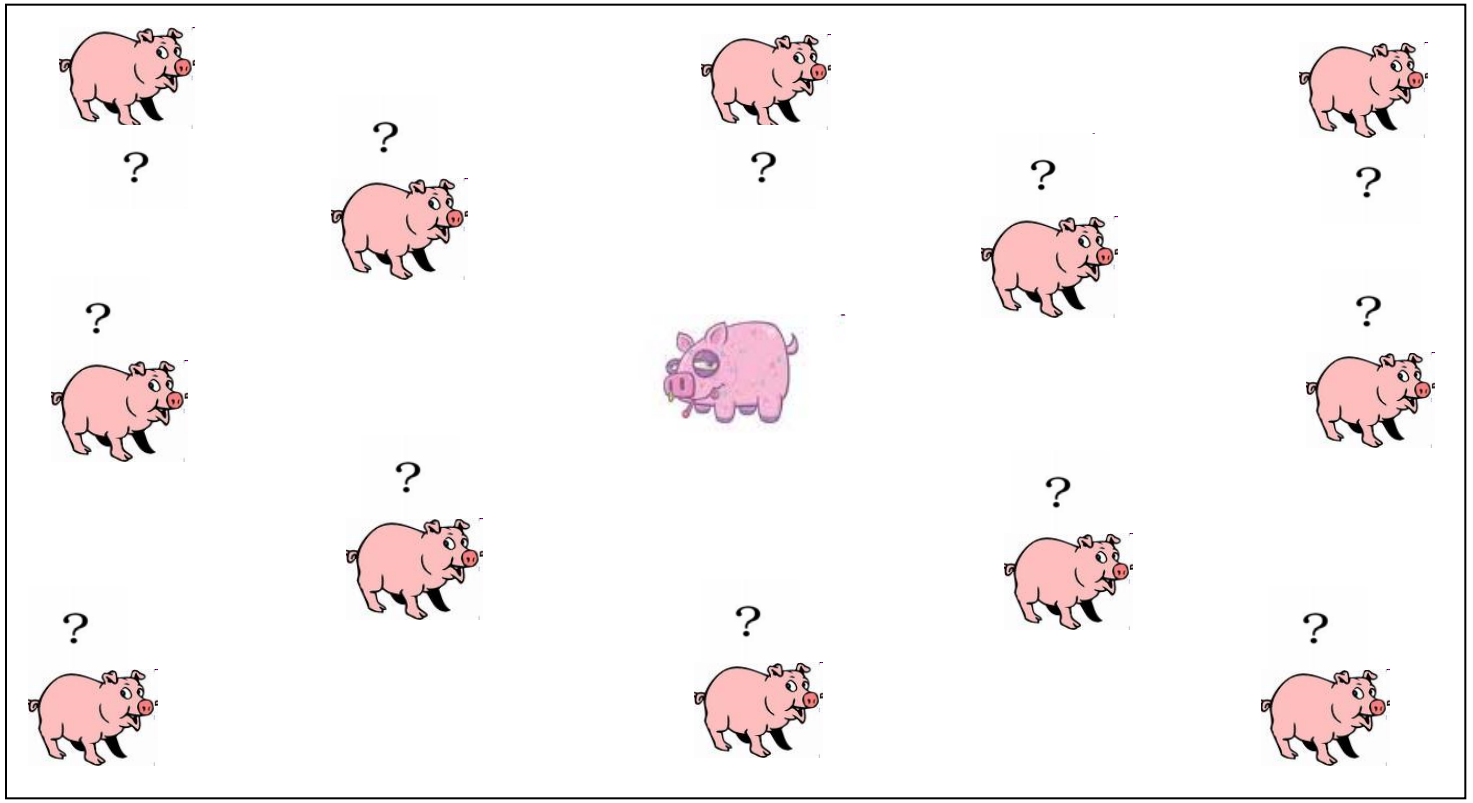

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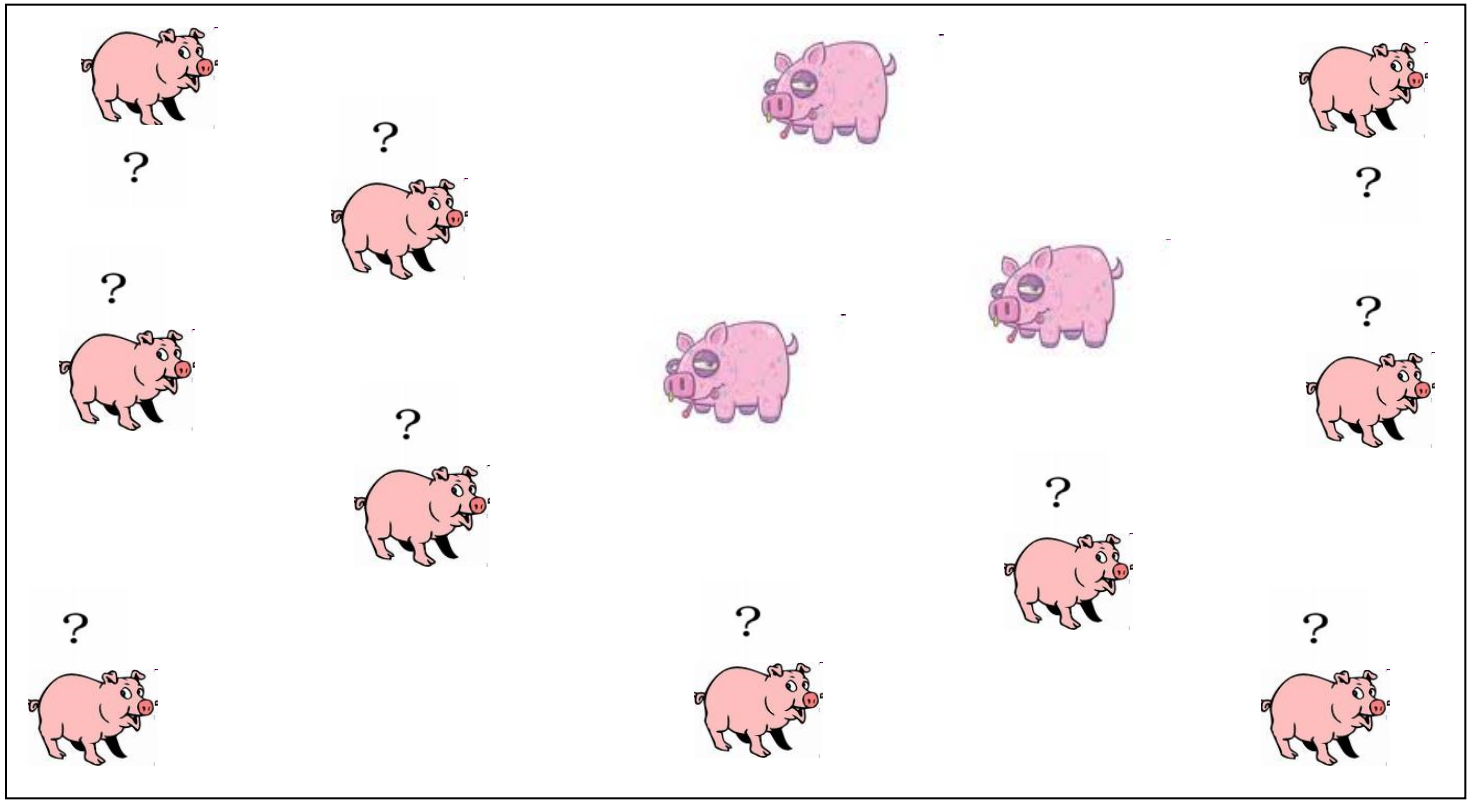

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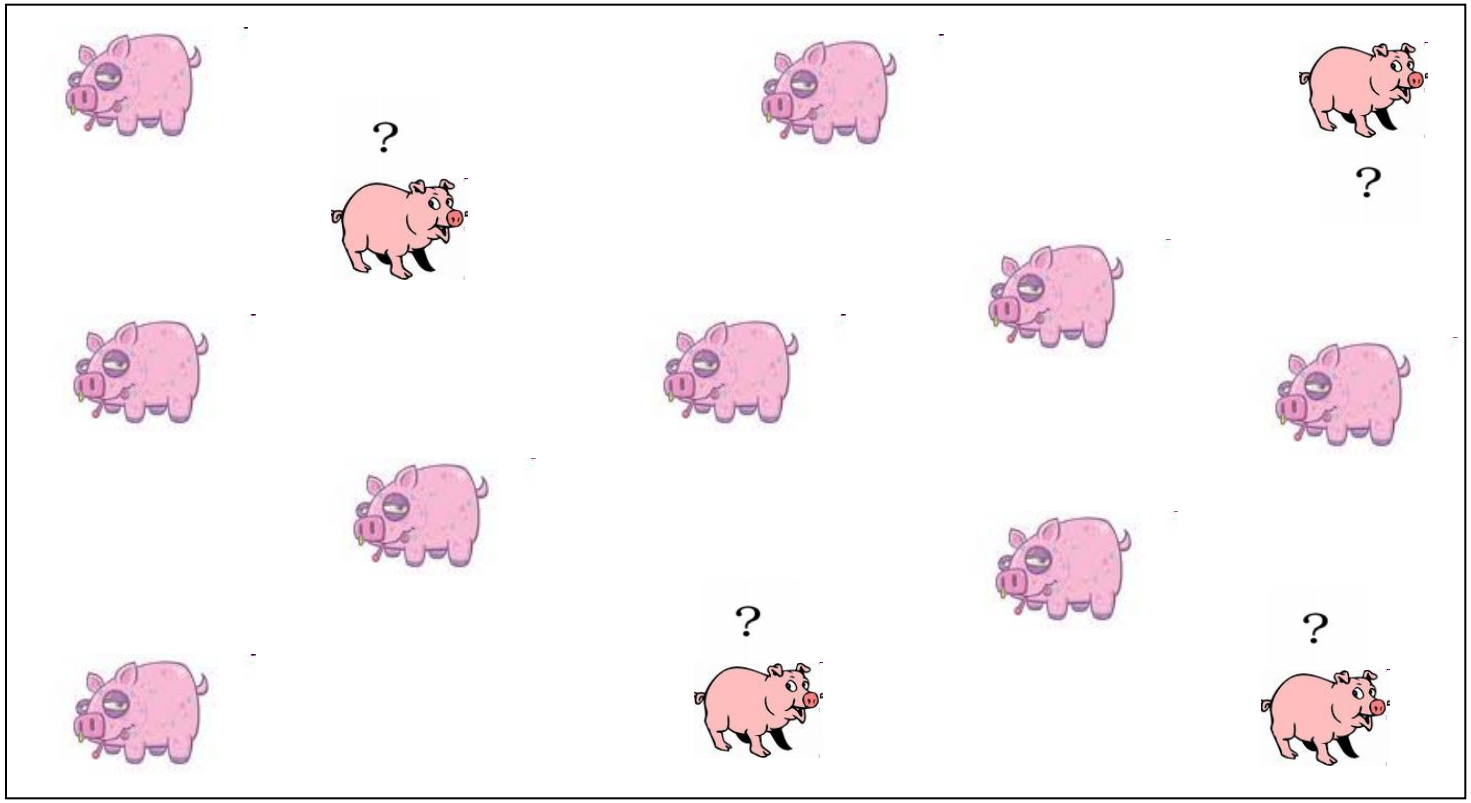

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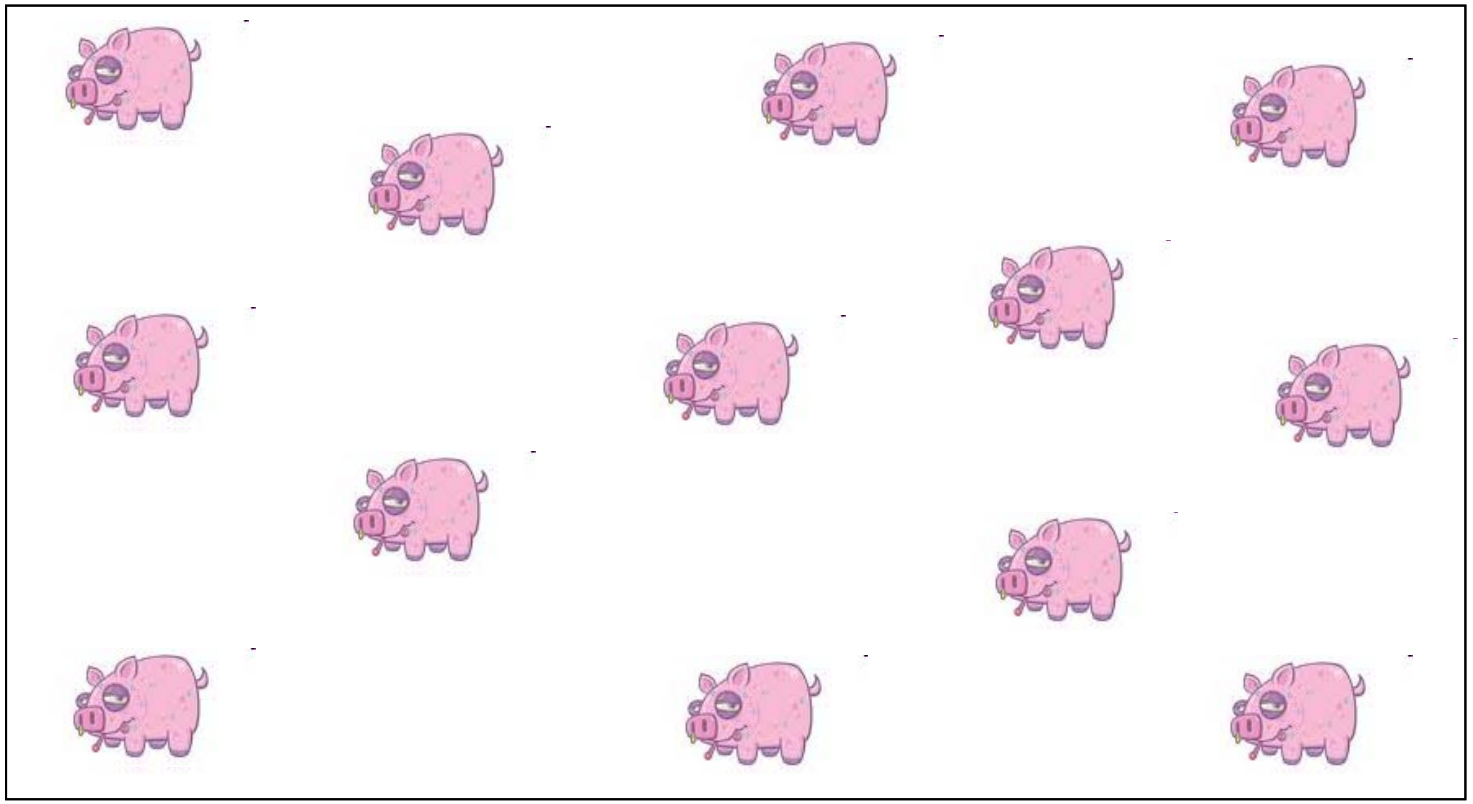

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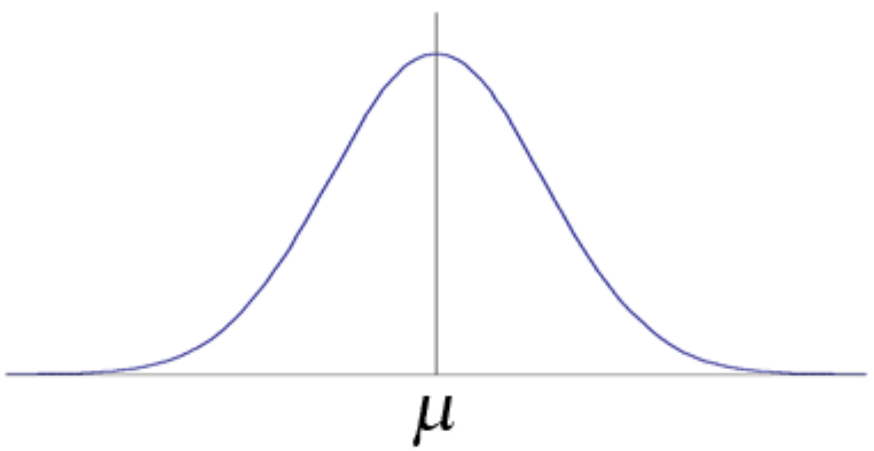
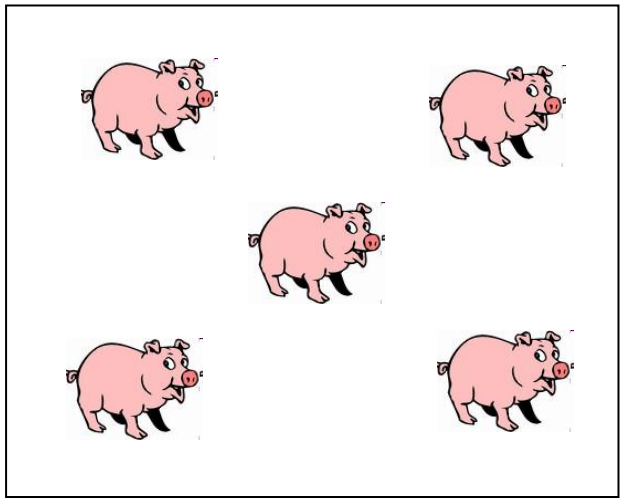
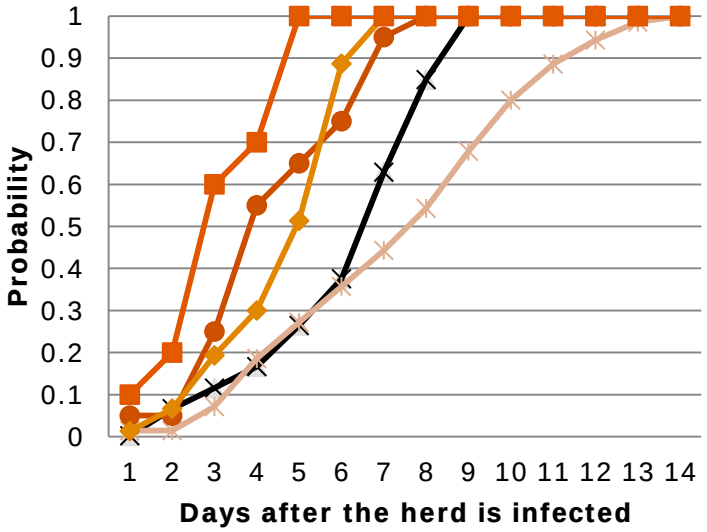


A herd model

DTU-DADS

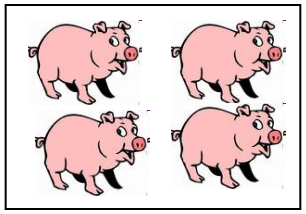


ISP and NAADSM



A country model

Susceptible



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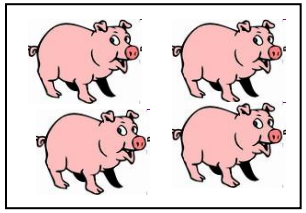
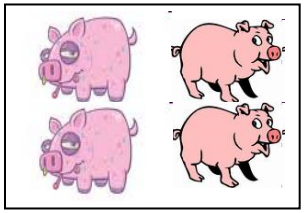


Infected herd



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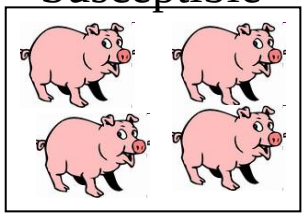

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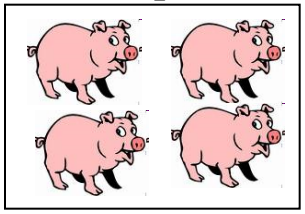
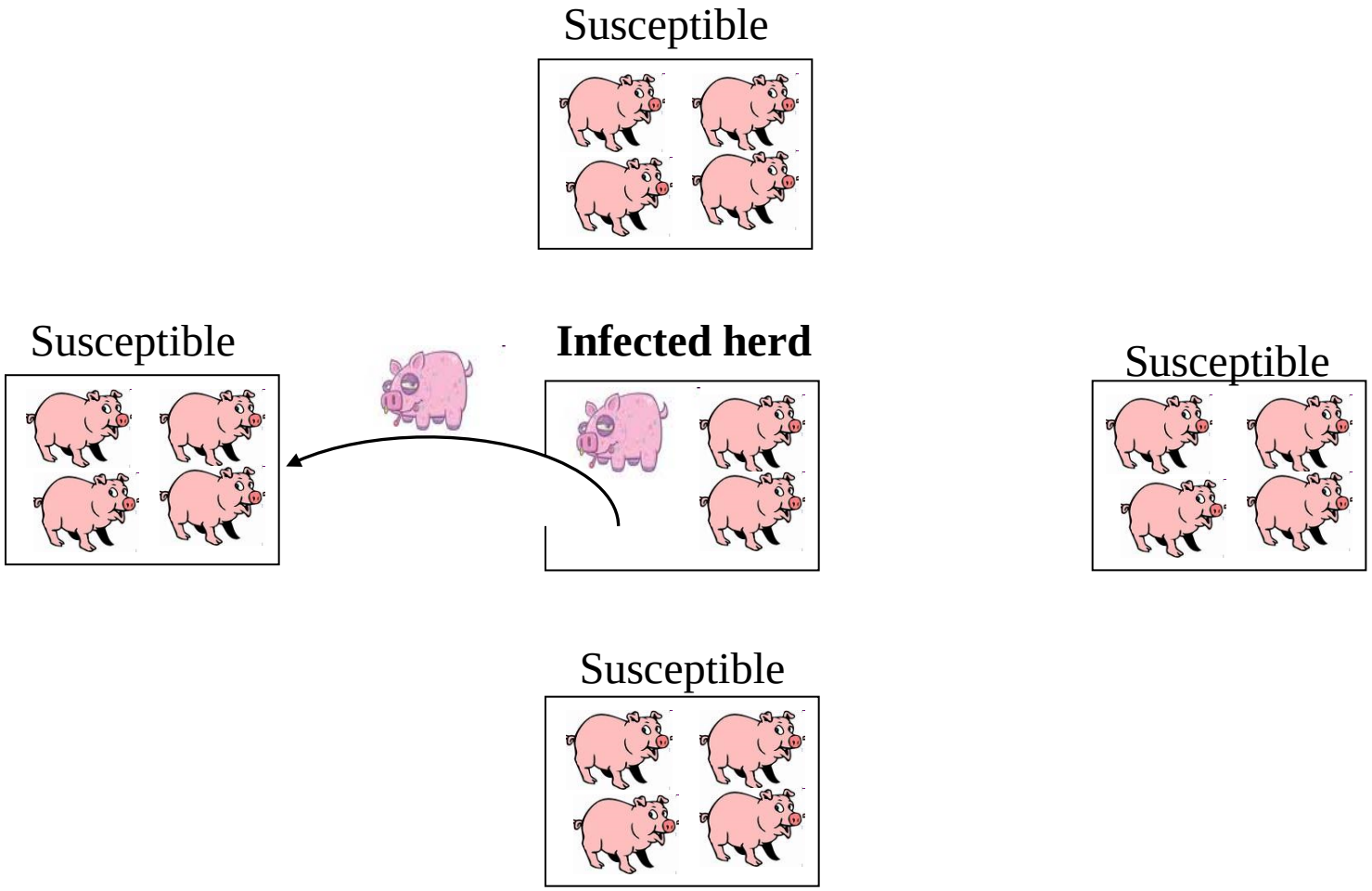
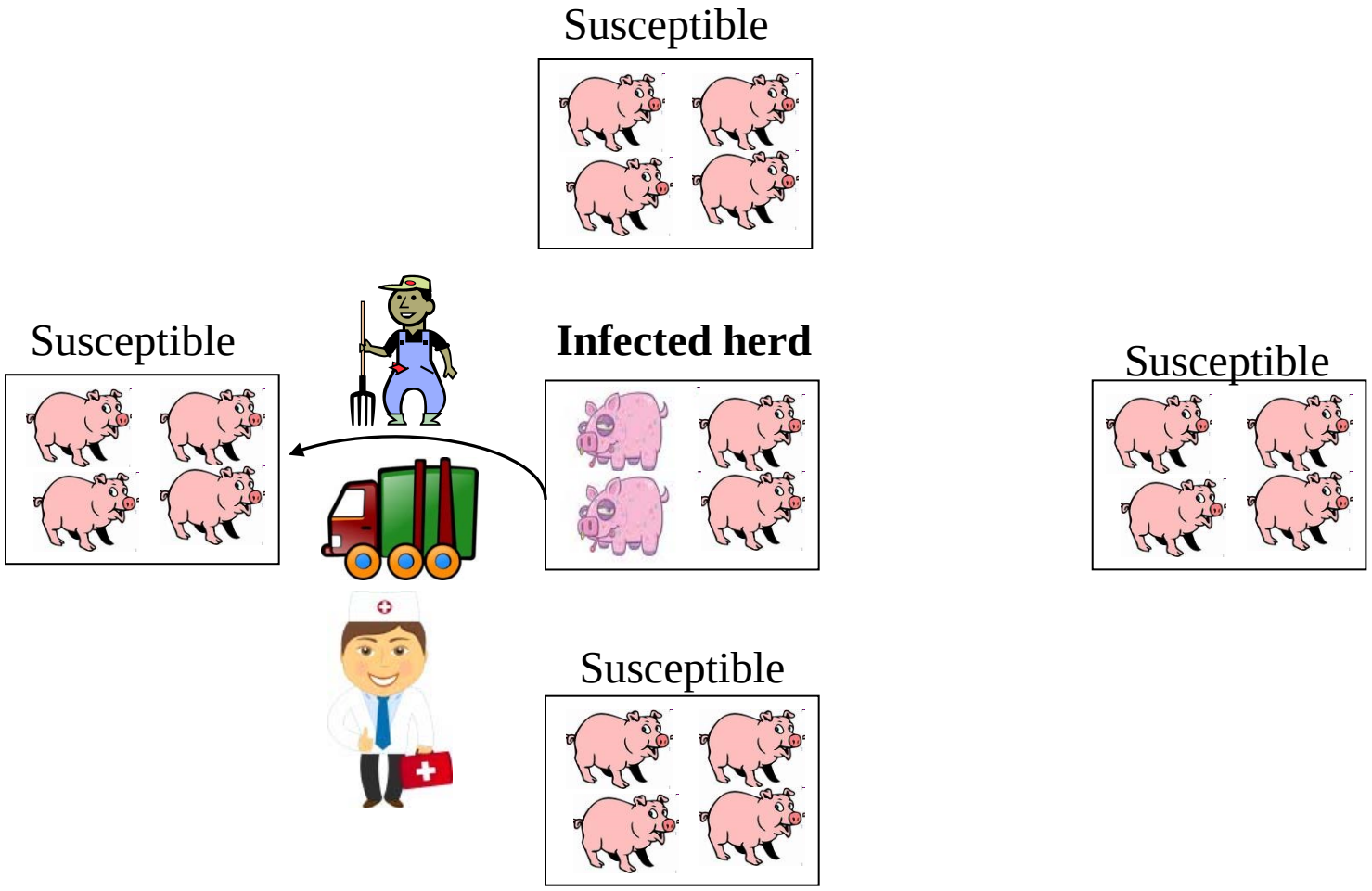


A country model



A country model



A country model

– How to model contacts?

- Separate movements and contacts patterns (DTU-DADS and ISP).
- Combining contacts (NAADSM).

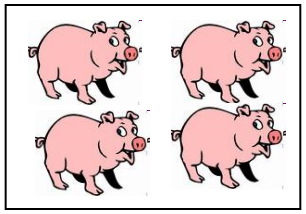
A country model

– Probability of infection is determined by:

- Distance-probability function (herd locations and movement data).
- Probability of contact between the 2 herd types (movement and contact data).
- Probability the contact is infectious (the literature).

A country model

Susceptible



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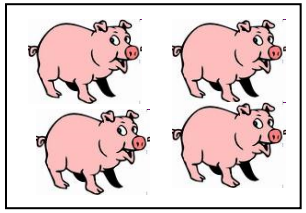
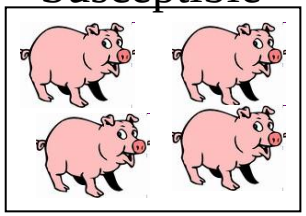


Detected herd

Susceptible



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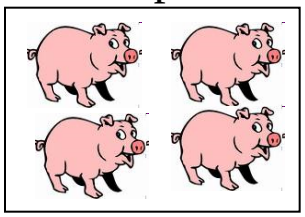
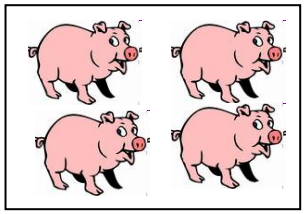


Control – pre-emptive depopulation

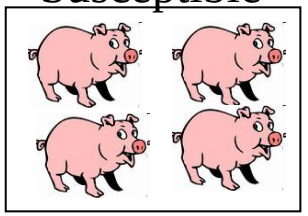
Susceptible

Susceptible



Detected herd

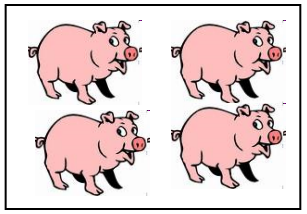
Susceptible



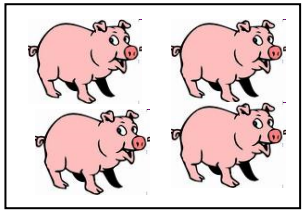
Susceptible

Control – emergency vaccination

Vaccinated



Susceptible



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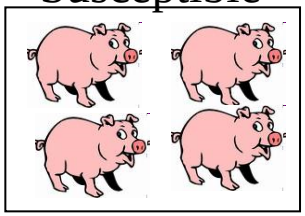

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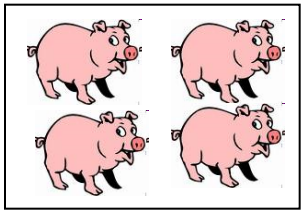


Control

– Start of the control measures:

- Days following disease detection.
- Following detection of a number of infected herds.

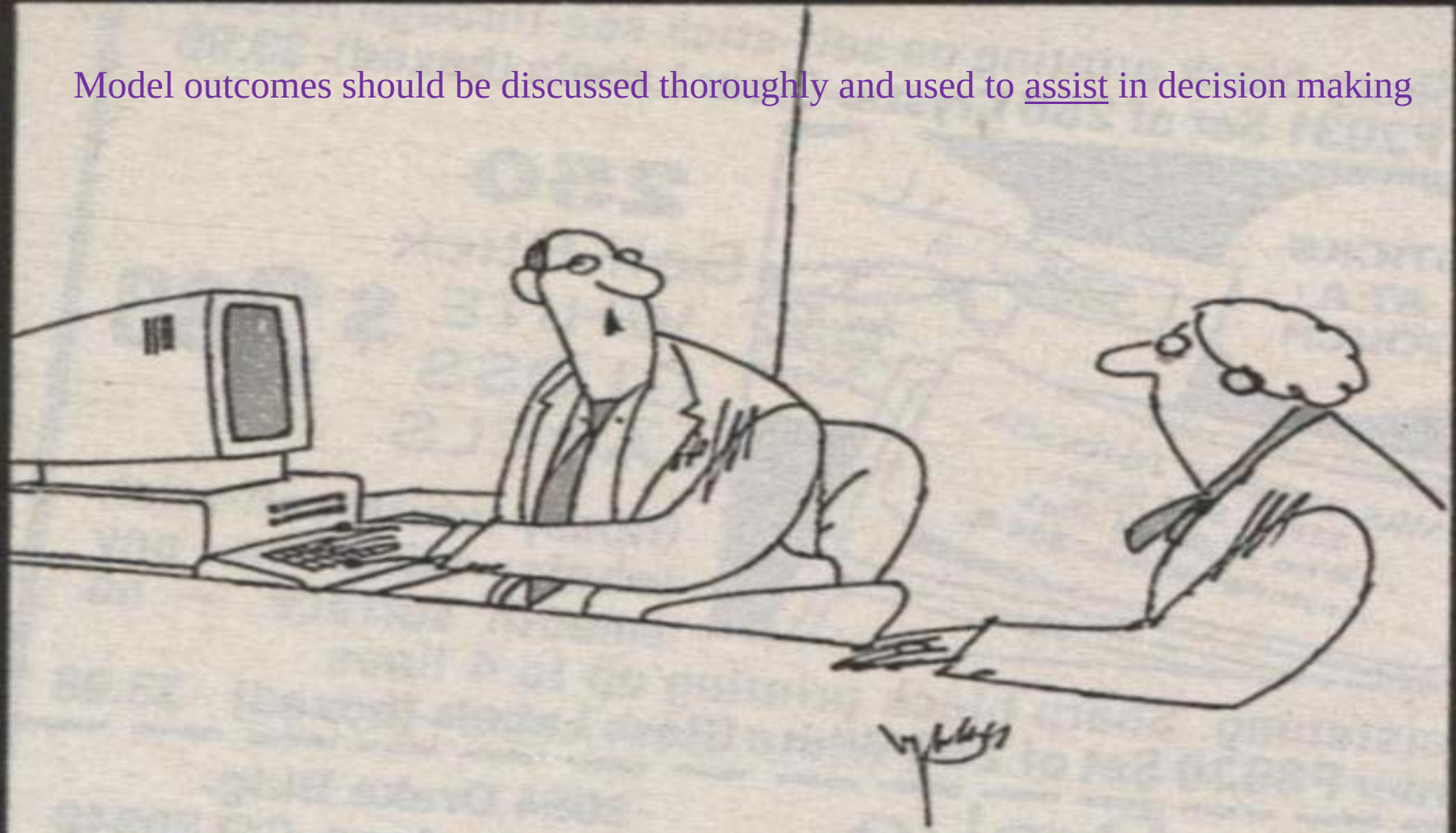
Summary

- A useful FMD simulation model on country level can be built when this information is available:
  - Location of herds, herd sizes and types.
  - Movement patterns from and to herds.
  - Policies and capacities for FMD control.
  - Other inputs from the literature.

Summary

- A useful FMD simulation model should:
  - Represent the herd structure.
  - Represent the dynamics of movements and contacts within the country.
  - Represent the biology of the disease.
  - Represent the regulations, roles and policies.

Model outcomes should be discussed thoroughly and used to assist in decision making



"I typed in your description of the symptoms. The computer says you have Dutch elm disease."